

## John T. Anderson Engineering Note

**Date:** November 11<sup>th</sup>, 2002

**Rev Date:** November 13<sup>th</sup>, 2002

**Project:** General D-Zero Electronics

**Doc. No:** A1021111

**Subject:** Correct implementation of MIL-STD 1553 interfaces on D-Zero detector electronics

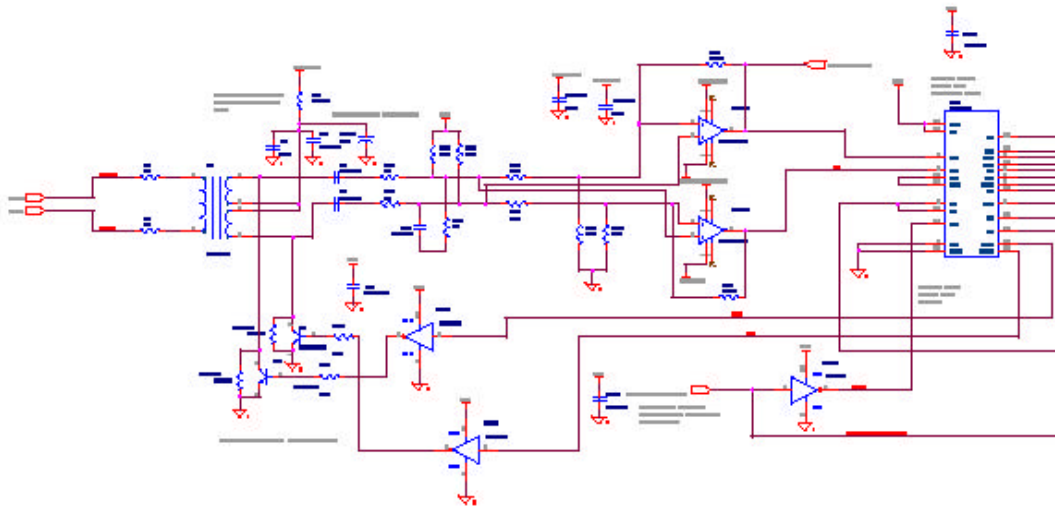
### ***Introduction***

The MIL-STD 1553 serial communications protocol is used throughout the D-Zero detector for control and monitoring of electronic systems. MIL-STD 1553 is robust and designed to withstand a great deal of interference, but correct implementation of the interface electronics is necessary to insure reliable performance. Numerous devices have been constructed in the last few years at the experiment that suffer from poor signal quality. Investigations led by Shoua Moua show that particular deviations from older implementations are the root cause. This document will re-examine the standard interface circuit, show where things have changed over the years, and provide a checklist for board developers to insure that future interfaces work optimally.

This document could not exist without the diligence and effort of Mr. Moua. My name really shouldn't be on this note, his should. I'm merely the collator and secretary.

### ***A typical MIL-STD 1553 interface***

Figure 1 is a portion of the Analog Front End (AFE) schematic, showing the MIL-STD 1553 interface circuit. It is representative of a typical implementation.



**Figure 1 - Typical MIL-STD 1553 interface circuit**

At this magnification, specific values are too small to read. Information on component values will follow. However, the basic circuit flow can be traced here easily. Connection to the 1553 cable is made at the left, via a transformer that is connected in series with resistors. The secondary windings connect to comparator stages that feed the Manchester encoder/decoder chip at the right. Serial output from the Manchester chip feeds back through inverter gates that drive transistors connected to the transformer secondary. The center tap of the secondary is held at a voltage, so that the transistors form a push-pull configuration to drive data back out the primary to the cable.

## Historical Issues

The nominal transformer used for the 1553 interface is the Pulse Electronics PE-5767, a 2:1:1 turns ratio part. This part is no longer manufactured. Mr. Moua has researched equivalent cross matches and has recommended using the PCA EP15767 transformer. Another manufacturer, Rhombus Industries, lists their T-50137 as a cross to both the PE-5767 and the EP15767.

At some point in the past, many boards have been manufactured using a different transformer from Pulse, the PE-5769. The PE-5769 has the same form factor and turns ratio as the PE-5767, but other parameters are significantly different. The PE-5767 data sheet is unavailable, but for the comparison the data sheet for the Rhombus Industries T-50137 is used.

Parameter	Pulse PE-5769	Rhombus T-50137 (Pulse PE-5767 equivalent)
Open circuit inductance	500 uHy	5000 uHy (min)
Leakage inductance	1.1 uHy	3.6 uHy (max)
Interwinding capacitance	11 pF	33 pF (max)
Primary dc resistance	1.3 ohms	3.9 ohms (max)
Secondary dc resistance	0.7 ohms	2.0 ohms (max)
Primary E-T constant	8.5 V-us	25 V-us (min)
Rise time	5.6 ns	10.5 ns (max)
Isolation	500 V	500 V (min)

## Effects on Circuit Performance

Use of the PE-5769 instead of the PE-5767 (or equivalent) *violates the MIL-STD 1553 specifications*. The inductance is too low and a sufficient number of boards with this transformer on a single cable will present too large a load to the driver, resulting in data transmission error. Further, the smaller E-T constant indicates that the core of the PE-5769 requires less current to saturate the transformer. Use of this transformer with the normal transistor drivers shown in the circuit of Figure 1 will, on occasion, result in bad data transmission from board to host due to core saturation.

## Deviations from Correct Circuit Values Caused by Well-Intentioned Designers

Faced with a historical background of using the PE-5769 instead of the correct part, various detector electronics boards have “tweaked” the interface circuit to compensate for the initial error of using the PE-5769. These include:

- Changing the series resistance between the primary of the transformer and the 1553 cable.
- Manipulation of the base current into the driving transistors to try and avoid saturation of the secondary.
- Addition of shunting resistances across the driving transistors to create bucking DC fields in the transformer core, again, to avoid saturation.
- Sorting driver transistors for a limited range of beta to reduce current and avoid core saturation.

Creativity of each solution notwithstanding, the only way to make the system really work is to fix the root cause – using the wrong transformer. After that, “tweaked” circuits need be brought back into compliance with the MIL-STD 1553 specification by then using the *correct* part values associated with using the *correct* transformer.

## Insuring sufficient drive current

Another factor influencing error rate is the drive current provided by the board to the cable. Recall that any given board may drive a cable with 30 loads on it. A circuit may work very well on the test bench with only itself and a computer interface present, but fail when faced with 30 loads in the pit. With fully loaded cables, any given board may have to drive over 200mA through the secondary of the transformer to assert sufficient voltage at the receiver. This sort of switched current also leads to big transients on the power supply unless there is a significant (tens of uF) capacitor nearby.

## Checklist for present and future designs

Figure 2 shows a close-up of the components that are commonly incorrect in the 1553 interface circuit. In Figure 2, many of the values shown are WRONG, and the common errors highlighted. The following checklist gives more detail, and is taken from Mr. Moua's research.

1. All MIL-STD 1553 interfaces shall use the PE-5767, PCA EP15767 or Rhombus T-10537 transformer, *not* the PE-5769. Mr. Moua has a small stock of the PCA EP15767 parts available.
2. The series resistance between the transformer primary and the 1553 cable shall be equal to 0.75 of line  $Z_0$ . For the cable used at D-Zero, use either 51 ohm or 56 ohm resistors.
3. No shunting resistors of any kind shall be used across the driving transistors. They needlessly waste current.
4. The series base resistance into the TN3725A transistors shall be 432 ohms,  $\pm 10$  ohms. 432 ohms is easily obtained in surface mount packages, it is a standard 1% resistor value.
5. TN3725A transistors should be used preferentially. Type 3725 transistors are very similar but exhibit a larger  $V_{BE}$  drop at larger collector currents, and can not handle as much collector current as the 3725A.
6. Insure that the power supply at the secondary center tap can supply at least 200mA of current, is heavily bypassed, and that the amplitude of the driven signal does not decay over 32-word transfers from board to controller.

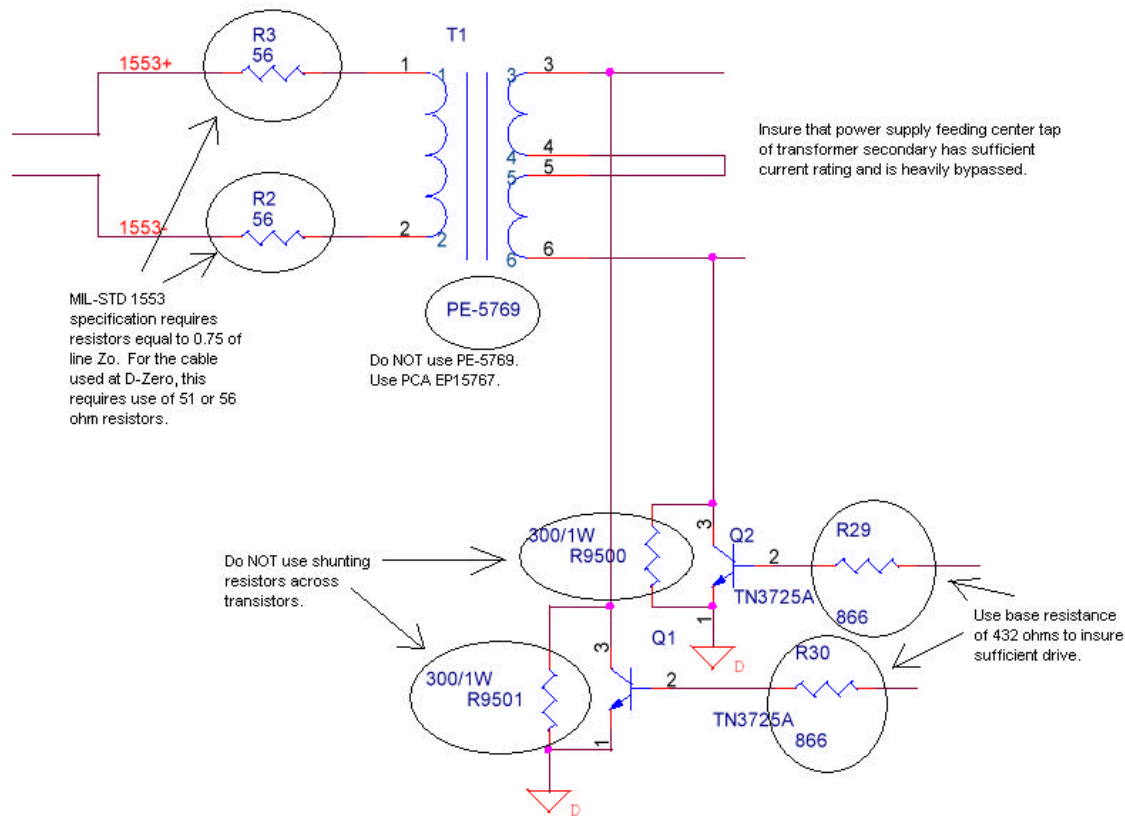


Figure 2 - Circuit section showing common errors

## Verification of correct operation

The best verification is done using a dual-channel oscilloscope. Connect channel 1 to one conductor of the twinaxial cable, channel 2 to the other conductor of the pair, and the scope ground to the outer shield. Invert channel 2 and add the channels to display the differential waveform. When hooked up into the system, verify that the output drive voltage of the board is no less than 7 V, peak-to-peak, at the far end of the cable. Further verify that the first two data bits are the correct width. The time from the first transition of the waveform to the second transition must be 1.5 usec,  $\pm 0.05$  usec.